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ENGINEERING GEOLOGICAL TYPOLOGY OF NEOGENE SEDIMENTS OSTRAVA BASIN CHARACTER FOR FOUNDATION ENGINEERING PURPOSE

Abstrakt

V Ostravské pánvi je v současné době v problematice inženýrské geologie a zakládání náročných staveb důležitým prvkem charakteristika předkvarterního podkladu. Častým problémem bývají horniny neogénu – spodního bádenu (miocén). Nemyslí se tím jeho samotná geometrie (hloubku uložení), která je již poměrně dobře prozkoumaná, ale jeho fyzikálně-mechanické a petrografické vlastnosti. Cílem studie byl proto výzkum charakteru neogenního předkvartérního podkladu, výstupem pak inženýrskogeologická typologie (tzv. místní charakteristiky) jeho vlastností jako pomůcka pro organizace a firmy zabývající se inženýrskogeologickým, geotechnickým průzkumem, zakládáním staveb v této významné městské aglomeraci.

INTRODUCTION

Pre-Quaternary bedrock feature is a significant constituent of an engineering geology and exacting building construction especially in Ostrava Basin. Neogene (lower Baden – Miocene) rock is the issue not Carboniferous. Depth of occurrence of Neogene deposits is well known, but the physic-mechanical properties and petrography.

Exacting buildings are found about 5 – 18 meters depth, and this depth is the most important. Absence of the space in the cities, subsurface car-ports, city infrastructure, etc. leads to a necessity of building foundation into the lower depth not only the exacting buildings. In Ostrava Basin, the gravel terrace properties are insufficient to foundation or the building geometry interferes with this geological structure and therefore the foundation into the Pre-Quaternary bedrock is recommended.

In the regard of engineering geology, Miocene formation is considered to a monotonous. This idea is out-of-date now. Several problems occur during e.g. the speedway D47 and collector channel construction, and these problems result in the significant diversity of Miocene formation development and thus result in the changes of physic-mechanical properties. Either the Neogene rock has the low bearing value or it behaves as a semirock in the shallow depth.

Aim of this project is to investigate the Pre-Quaternary rock and create the engineering geological typology of its properties. The engineering geological typology will help the organizations or companies concerning with engineering geology, geotechnical investigation, and foundation engineering in the Ostrava city agglomeration.

NATURAL CONDITIONS

According to a regional geology, the area of interest belongs to Ostrava Glacial Basin that is a part of front Carpathian fore-deep of Outer Western Carpathians.

Pre-Variscian crystalline basement called brunovistulikum is underlying of Neogene (Havlena, Dudek, 1978). Brunovistulikum contains migmatites and migmatitic paragneiss. Upper components are Moravian Karst Devonian deposits, and Lower Carboniferous Culm. Upper Carboniferous

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sediments begin with basal coarse grained sandstone, subsequently siltstone with rooty aleuropelite, coal seam, and, finally aleuropelite or pelite with the limnic, brackish or sea fauna (Chlupáč a kol., 2002).

Quaternary sediments represent the cover of the fore-deep autochthon Miocene deposits. They contain Holocene fluvial deposits of lower and upper alluvium plane and anthropogenic deposits such as backfills and dumps. Pleistocene deposits represent glaci-fluvial, fluvial, deluvial deposits, loess loam, and Tertiary eluvia.

Hydrogeology of Neogene and Quarternary

The area of interest belongs to Odra River basin, hydrology order 2-01-01 (Michlíček a kol., 1986).

Basal clastics of karpat developed only in deeper part of Carboniferous paleorelief, and do not create geologically or hydraulically continuous lay. In the point of view of hydrogeology, this structure has the character of a flaser with confined aquifer. The groundwater is fossil, syndepositional and with no earth ground circulation.

Aquiclude is represented by a silty clay deposit of karpat – brown and grey layers.

Significant aquifers are localized in the layers of disintegrated sandstone or sand and in the layers of grey facie or in the flaser sand with gypsum.

Lower baden basal clastics including detrital sediments lay on the weakened, strongly disintegrated and weathered Carboniferous rock. Together with it creates the confined aquifer. Human activity strongly influences this confined aquifer. Detrital sediments were developed in the east of the area of interest in two connected Dětmarovice and Bludovice scours.

Lower baden pelite represents the aquiclude. Sandy layers of the same geological unit are saturated by the fossil sea water and it represents the stationary system and confined aquifer. The aquifer is represented by fine grained sand and low consolidated sandstone curved due to a different contraction of Lower Baden pelite that has great thickness.

Quaternary sediments are wide spread in the area of Ostrava Glacial Basin. They are included in the effluvial gravel-sand and in the Odra, Ostravice and Olše River terraces. Two types of terraces are known in the hydrogeological point of view. Main terrace consists of gravel to gravel-sand pertaining to Elster to Saal Glaciation. Valley terrace consists of fluvial gravel-sand to clayey sand and deposits of Pre-Elster Glaciation valley. This valley lays 60 – 100 meters bellow the valley terrace and it is filled with fluvial sand to gravel-sand and send with the clayey intercalation.

Quaternary saturation concentrates in a pore system – sand, gravel-sand; the water is an atmospheric origin. It keeps oxidized environs within the area of intensive circulation with the earth ground. Groundwater is utilized to waterworks purpose (Dopita et al., 1997).

Miocene Stratigraphy and Litology

- ❑ KARPAT SEDIMENTS

Bedrock of Karpat sedimentation basin is represented by Carboniferous rock, above the karpat sediments lays the Outer Carpathian Nappe lays. Lithic facies of karpat units are influenced by various subsidence rate, various salinity of sedimentation area, and variance of basin bottom. In Ostrava Region, karpat divides into 5 general lithological types (Dopita et al, 1997; Martinec, Krajíček, 1990).

a) <u>Local depression clastics</u> – lay on the karpat base. Clastics are represented by sandy gravel, low consolidated sandstone and fine grained conglomerate with prevailing Carboniferous material. Thickness reaches a several decades of meters.

b) Varied basal siltstone – as an accumulated Carboniferous geest arisen before karpat transgression in brackish environs or in the coastal lakes. The clayey siltstone is bluish or greenish to grey. Maximum thickness is 70 meters.

c) Brown beds deposited at first in shallow lagoons with fluctuating salinity then in the sea environs. It contains browny grey to dark grey claystone that is both limy and non-limy.

d) The most spread grey "schlier" beds developed both in the shallow and deep neritic environ. They lay on the varied basal siltstone or brown beds. At the upper parts of Carboniferous relief lay just on the Carboniferous. They contain greenish or bluish grey limy micaceous claystone with variable sand content and with the clayey sandstone lamination.

e) Beds with gypsum content – their character is affected by shallow neritic and shallow lagoon environs. They contain green and foxiness to red limy claystone. Irregular laminas of pink or white fibrous gypsum occur within them.

- BADEN SEDIMENTS

Baden sediments fill a part of Miocene fore-deep that was developed before nappe overthrust. The Miocene fore-deep reach about 15 km of spread in Ostrava Region (Dopita et al, 1997; Martinec, Krajíček, 1990).

a) Basal clastics – detritus – arisen after the erosion of Carboniferous surface before Miocene sea transgression and during this transgression. Basal clastics fill the toes of the erosion valley and Bludovice and Dětmarovice pothole bottom. Detritus contains coarse grained boulder breccias, boulder gravel, limy and clayey sand and gravel that is poorly sorted; with calcite cement. Gravel becomes to so-called beach sand near the upper margin of detritus creation.

b) Except the pelagic sediments, the coarse grained and unsorted breccias contain also deposits of terrestrial alluvia and diluvium. These sediments create the independent sedimentation cycle separated from above laying pelite.

c) Pelite – lays on the basal clastics due to a basin deepening. The area of sedimentation was well oxidised, far from the sea-coast, sporadically in deep depressions. Pelite represents greeny grey to grey limy clay with the variable carbonate content. It mostly contains silt impurity and fine grained sand lamination. Increased sandy lays accumulation is known at 2 elevations – upper sandy layers between +50 to -50 meters; and lower sandy layers between -400 to -450 meters at the area of Bludovice and Detmarovice pothole.

Locally, pelite contains acid tuff and tuffites.

METHODOLOGY OF STUDY

This project was solved in a several phases. During the 1st phase, the area of interest was specified. The characterization of Neogene was determined. The area of interest falls into a part of cadastral area of Ostrava. Sample collection proceeded as a planned investigation for various purposes during the 2nd phase of project realization.

Subsequently, properties laboratory research was realized including particle-size analysis, indexing property research (determination of consistency limits, water content, and porosity), determination of bulk density, density, shear strength, compressibility. The actual data was supplied with archive research delivered by K-GEO Company. Obtained data was evaluated and statistically processed during the next phase. Final phase proposes the engineering geological typology of Neogene sediments with the local characterization (Tab. 2).

TYPOLOGY

The statistic data set includes 405 boreholes that are recorded in JTSK coordinates; and these boreholes have registered the Neogene surface depth.

151 samples was collected from these boreholes and used to a laboratory research [7-15] of rock properties (Tab. 1).

Tab.1 Number of processed samples of given area

selected properties	*Number of samples*
water content	145
specific density	145
bulk density	148
dry sample bulk density	148
liquid limit	141
yield point	141
plasticity index	141
consistency index	138

selected properties	*Number of samples*
porosity	142
saturation	142
effective cohesion	75
effective angle of internal friction	75
cohesion intercept	37
total angle of internal friction	34
oedometric modulus	44

The samples were collected from pelite sediments of lower baden as a grey to blue grey limy, solid moist clay.

Neogene depth below the earth surface varies from 1.8 to 19.0 m (SW of area of interest 5 – 17 m, SE 2 – 17 m, NW 7 – 15 m).

With the respect to the lutaceous Neogene, above mentioned literature and soil recovery the foundation soil is assumed to be fine grained soil.

The *soil classification* was processed according to ČSN 73 1001 Standard. For this purpose the *grain-size curves* and plasticity chart were used. Based on these graphical representations, the soil classes were determined. These classes describe Neogene sediments of area of interest.

Grain size distribution is determined by the grain-size analysis. It represents the grain distribution in the soil according to its size. The amount of the particular grain-size fraction is transferred to a percentage. The result of this analysis represents the grain-size curve. Grains greater then 0,1 mm is SIEVE through the set of mesh screens. Grain-size under 0.1 mm is determined by the hydrometrics test. Fig. 1 (according ČSN 73 1001 Standard) shows that lower baden sediments are well sorted. Dash line represents the grain-size curves of fine-grained sandy soil; solid line represents the envelope curve of all determined grain-size curves of clayey soil.

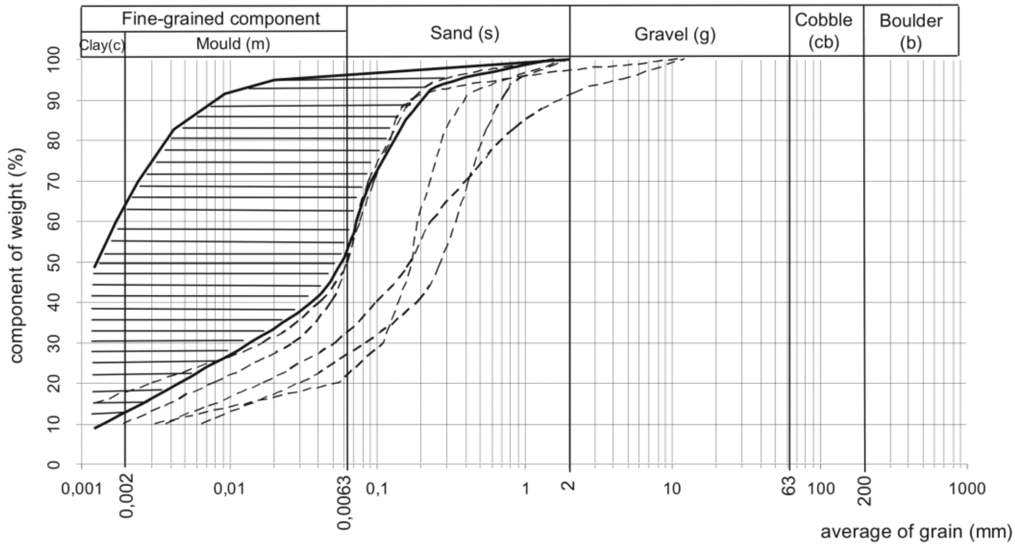


Fig.1 Envelope curves grain-size curves determined soil

envelope curves fine-grained soil

grain-size curves of fine-grained sandy soil

Yield point w_P represents the moisture of yield point when the solid state soil becomes plastic. Determination of yield point is given by ČSN 72 1013 Standard. During the laboratory test, the soil sample is shaped as a cylinder with the 3 mm diameter. When the cylinder begins to fall into 1 cm long pieces, the moisture is established. Figure 2 shows the rate of yield point varies from 10 to 45 %, the most frequent rate is between 20 – 30%.

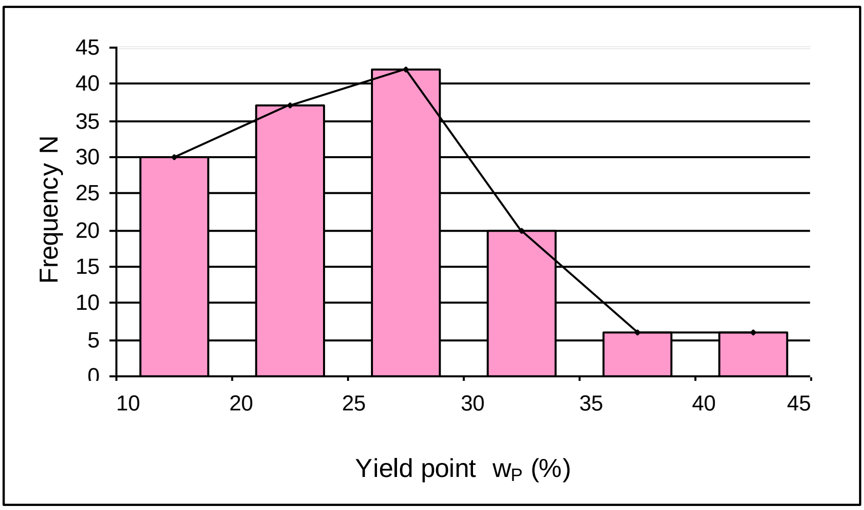


Fig.2 Dependence of yield point on frequency

Liquid limit w_L represents the moisture of yield point when the soil loses the strength and becomes liquid. This moisture rate is established by means of Cassagrande concave tool. The Cassagrande concave tool with the cut in two soil sample 25 times taps at the base block with the rate of 2 hits per second (according the ČSN 72 1014 Standard). The two parts of soil moisture should put together for 12.5 mm.

Evaluation of liquid limit is shown at the Figure 3. It seems the clayey soil is predominately high plastic (55 – 70%). This result corresponds with Martinec and Krajíček (1990). Soil with low (17 – 35%), intermediate (35-50%) and extreme (70 – 90%) plasticity is less frequent.

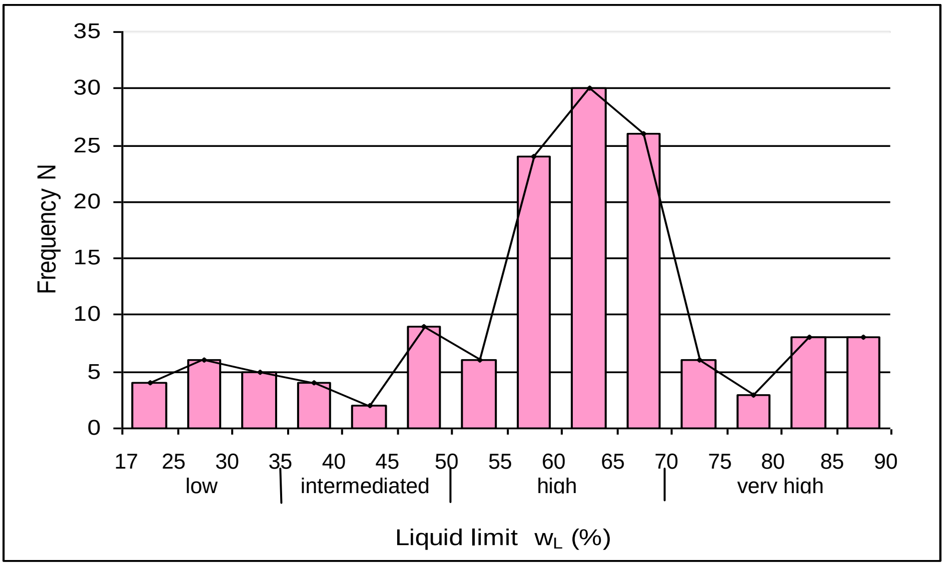


Fig.3 Dependence of liquid limit on frequency

Plasticity index in percentage represents the moisture range in which the soil is plastic (IP=wL-wP). It means, how much of moisture the soil should be charged to become from plasticity limit to yield point.

The plasticity index varies from 2.7 to 55%, whereas Martinec and Krajíček (1990) mention 10 to 60%. The most frequent rate of plasticity index varies from 30 to 45% (Fig.4). According to Atterberg classification, this range corresponds with clayey loam to clay. Lower plasticity index (less then 17%) corresponds with sandy soil and loam.

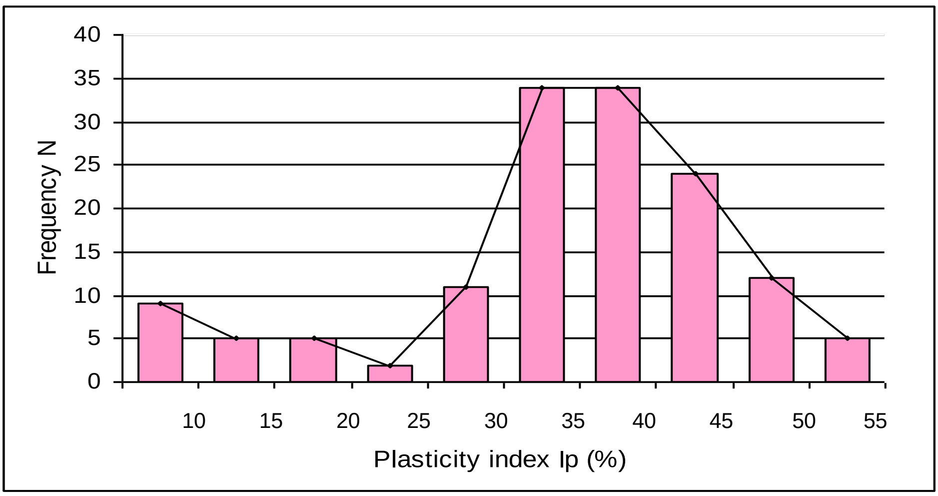


Fig.4 Dependence of plasticity index on frequency

Consistency index I_C reflects the state of consistent soil. The natural moisture of soil is compared with the consistency limits – w_L and wP. Consistency index helps to establish the Standard characterisation. Consistency index varies from 0.3 to 1.7 (Fig.5). The most frequent range is 0.5 to 1.0 – solid consistencies; and 1.0 to 1.5 – rigid consistencies (according to ČSN 72 1001Standard). This result corresponds with Martinec and Krajíček (1990).

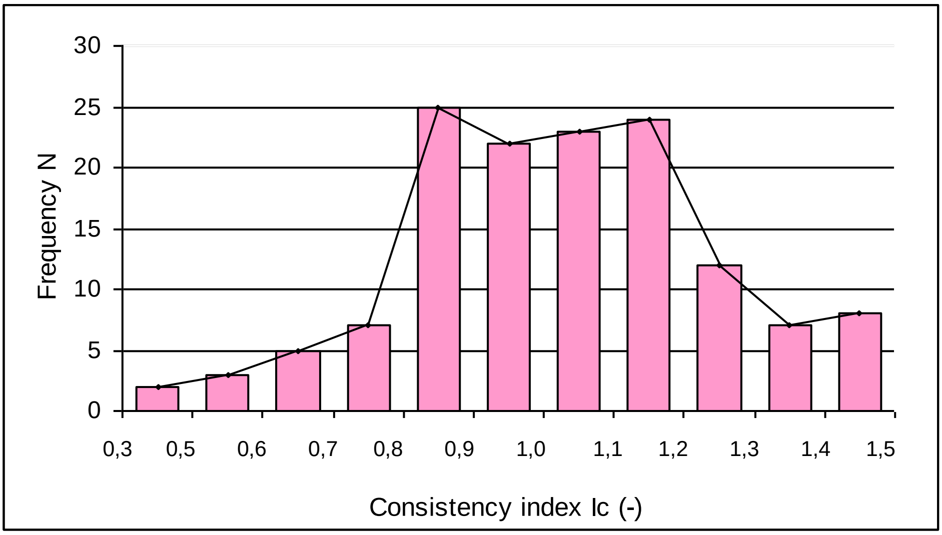


Fig.5 Dependence of consistency index on frequency

Plasticity chart is required for soil with the grain-size particles less then 0.5 mm (according to ČSN 73 1001Standard). It represents the dependency of w_L soil moisture on plasticity index. The plasticity chart is divided into two parts by a line Ip = 0.73 (w_L-20%). Fig.6 ratifies the high plasticity of clayey soil. Lower values have the soil with higher rate of silty or sandy aggregates.

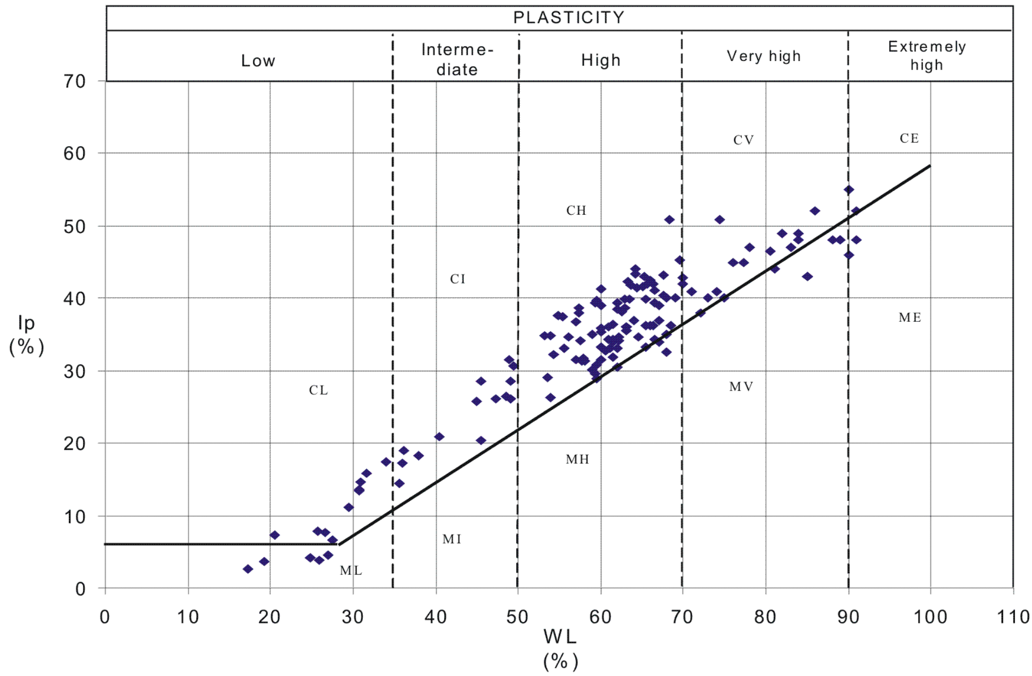


Fig.6 Plasticity chart of soil grain size under 0.5 mm (according to ČSN 731001 Standard)

According to the evaluation of above mentioned characterization the soil is classified into the classes: fine grained F8 – clay with high plasticity CH (58 % of all samples), clay with very high plasticity CV (11%); F6 – clay with intermediate plasticity CI (11%), clay with low plasticity CL (6%); F7 – loam (mould) with high plasticity MH (2 %), loam (mould) with very high plasticity MV (5 %), loam (mould) with extremely high plasticity ME (2 %), sandy loam (mould) MS and sandy clay CS (5%).

Physical properties are another of descriptive properties. They influence on soil mechanical properties as compressibility, consolidation, collapsibility, settlement etc.

Specific density ρ_s means relationship between density of soil particles and their volume. Specific density is determined according to ČSN 72 1011 Standard during the laboratory test as the weight of adjusted sample to its volume established by the pycnometer method.

Specific density of loam and clay varies from 2.7 to 2.75 g.cm-3 (Pašek, Matula et al., 1995). It means, the area of interest contains predominately clay, less frequently there occurs clay with loamy impurities or loam (see Fig.7), further sand, eventually clay with sand whose specific density reaches 2.67 g.cm-3.

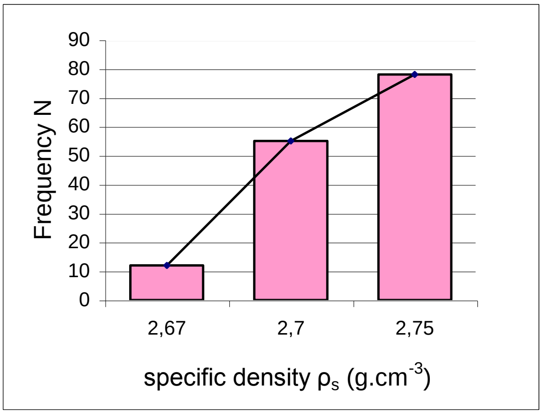


Fig.7 Dependence of specific density on frequency

Bulk density ρ represents ratio between soil density and its wet soil volume. Bulk density is required for calculation of relative density and porosity. It is determined according ČSN 72 1010 Standard.

Fig.8 shows that the range of bulk density varies from 1.8 to 2.2 g.cm-3. The most frequent value falls into 1.95 to 2.05 g.cm-3. This result corresponds to Martinec and Krajíček (1990). Bulk density of clay reaches 2.1 – 2.2 g.cm-3, silty loam 1.9 – 2.1 (Pašek, Matula et al., 1995). Bulk density below 1.9 g.cm-3 relates to occurrence of sandy or loamy particles.

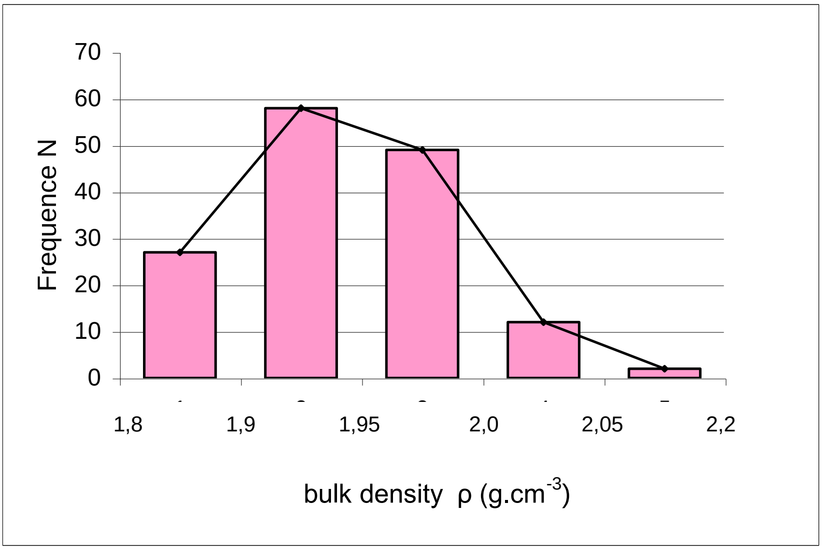


Fig.8 Dependence of bulk density on frequency

Dry bulk density ρ_d represents ratio between dry soil density and volume of original wet soil. Dry bulk density is required for calculation of moisture or saturation. Value of dry bulk density varies from 1.3 to 2.0 g.cm-3. The most frequent value is 1.5 - 1.7 (Fig.9).

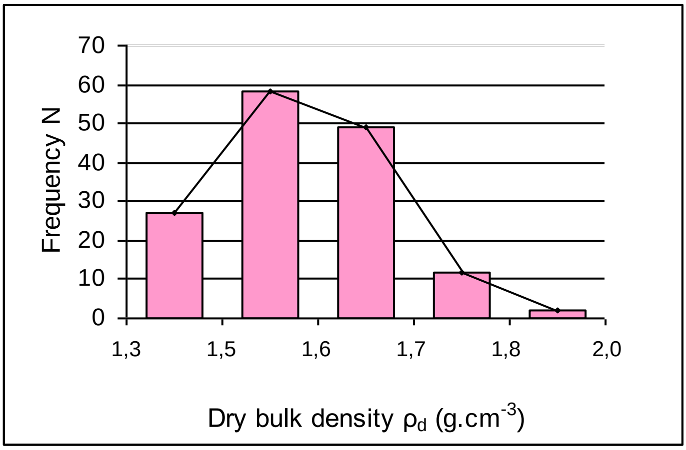


Fig.9 Dependence of dry bulk density on frequency

Porosity n means ration between volume of soil pores and total volume of soil. Porosity is calculated by means of bulk density and dry bulk density. It varies from 28 to 51 % (Fig.10). The most frequent range is 35 – 45%. The soil with porosity below 35% assumed to be sandy or loamy. According to Martinec and Krajíček (1990), the porosity varies from 20 to 30%.

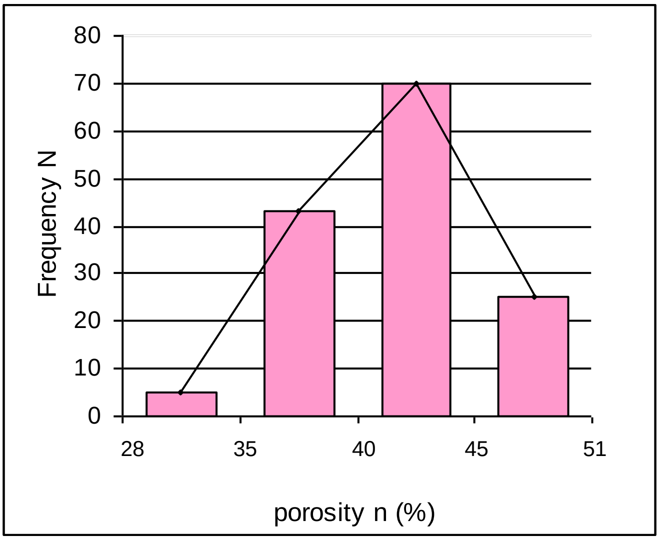


Fig.10 Dependence of porosity on frequency

Moisture Wn is a volume of water contained in soil. This water could be taken away by means of drying at temperature 105 and 110°C. Moisture could be calculated as a ratio between original soil density and dry density. Process of the laboratory test agree with ČSN 72 1012 Standard. Natural moisture content varies from 12 to 35%, the most frequently 20 – 30% (Fig.11).

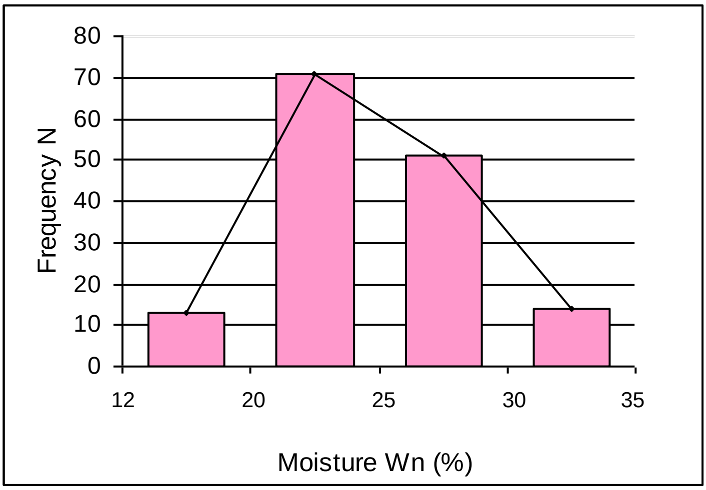


Fig.11 Dependence of moisture on frequency

Degree of saturation Sr represents a rate of pore water filling. It is ratio between water volume and pore volume. Very wet soil (according Myslivec, Eichler, Jesenák) has the degree of saturation 0.8 – 1.0 (Fig.12), these results agree with Martinec and Krajíček (1990).

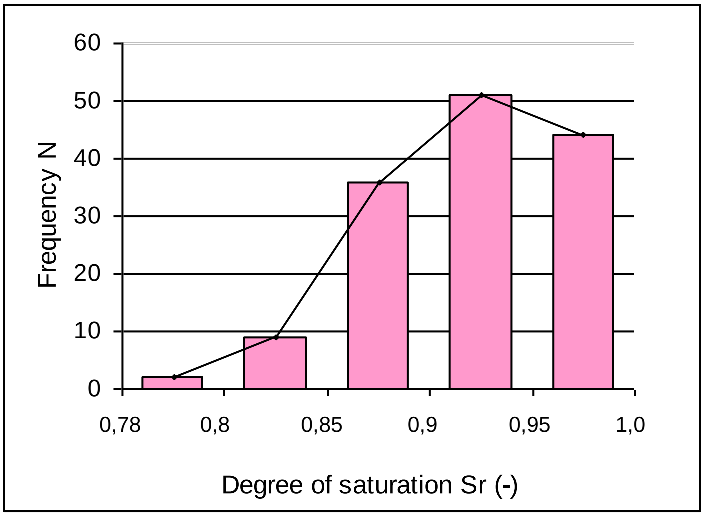


Fig.12 Dependence degree of saturation on frequency

Mechanical properties include shear strength that is characterized by cohesion and angle of internal friction; and modulus of deformation. These properties represent the behaviour of soil during the straining. Untold samples were available to this research.

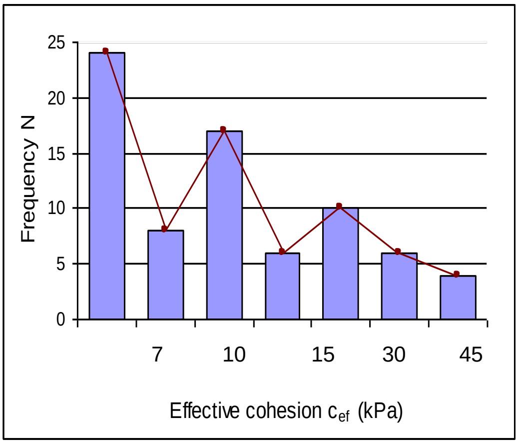
Angle of internal friction and cohesion represent the factors of shear strength. Internal friction is defined by the angle of internal friction; cohesion is defined by shear strength within the zero direct stress.

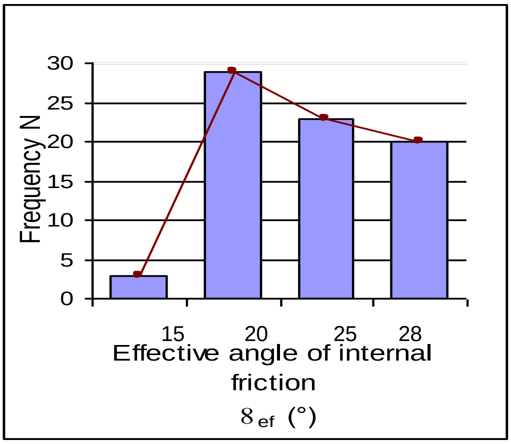
In case of *coherent soil*, the source of shear strength rises from internal friction between soil grains; and cohesion. The cohesion means relative structure of single parts and water. It is defined by shear strength within the zero direct stress.

In case of *incoherent soil*, the source of shear strength represents the internal friction between soil grains only defined by angle of internal friction.

Effective parameters of soil strength describe soil that is under influence of stress as long as the neutral pressure reaches zero thus the soil is consolidated (stress is transferred by grains only).

Effective cohesion falls into range of 5 to 30 kPa (Pašek, Matula et al, 1995), in case of our research the values vary from 7 to 80 kPa (Fig.13a). Effective angle of internal friction according to Pašek, Matula et al, 1995 reaches 18 to 30°, our research 14 – 28° (Fig.13b).



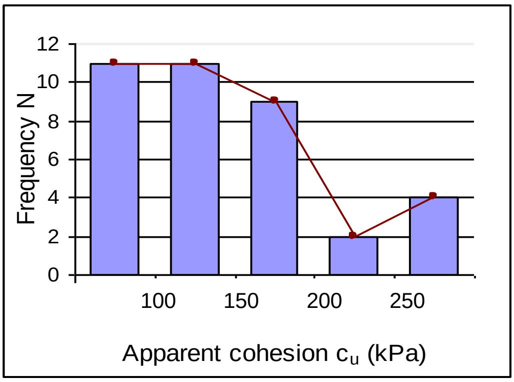


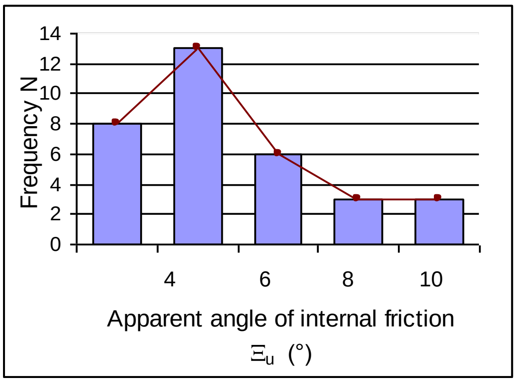
a) b)

Fig.13 Dependence of effective soil strength on frequency
a) Dependence of effective cohesion on frequency
b) Dependence of effective angle of internal friction on frequency

During the laboratory test of *apparent* parameters of soil strength, the pore water content is constant. The soil is disturbed as unconsolidated and undrained. Apparent parameters valid for given soil compactness and moisture. It is required for loading test.

Apparent cohesion varies from 30 to 280 kPa (Fig.14a), apparent angle of internal friction 1 to 17° (Fig.14b). According to Pašek, Matula et al, 1995 the apparent cohesion is 10 to 200 kPa, angle of internal friction is 0 to 25°.





a) b)

Fig.14 Dependence of apparent soil strength on frequency
a) Dependence of apparent cohesion on frequency
b) Dependence of apparent angle of internal friction on frequency

Constrained modulus E_{oed} describes the state of soil that could not be deformed owing to vertical stress – uniaxial compression. Compressibility is established during the uniaxial compression measurement in dependence on known stress in the oedometer. Consolidation should forego the laboratory test. Subsequently, the soil sample is gradually charged till the maximum stress; finally the sample is released. Dependency of proportionate deformation and the stress is represented by compressibility curve.

According to Pašek, Matula et al, 1995, the constrained modulus values vary from 8 to 39 MPa. In case of our research, these values reach 5 to 45 MPa, the most frequently 5 to 20 MPa (Fig.15).

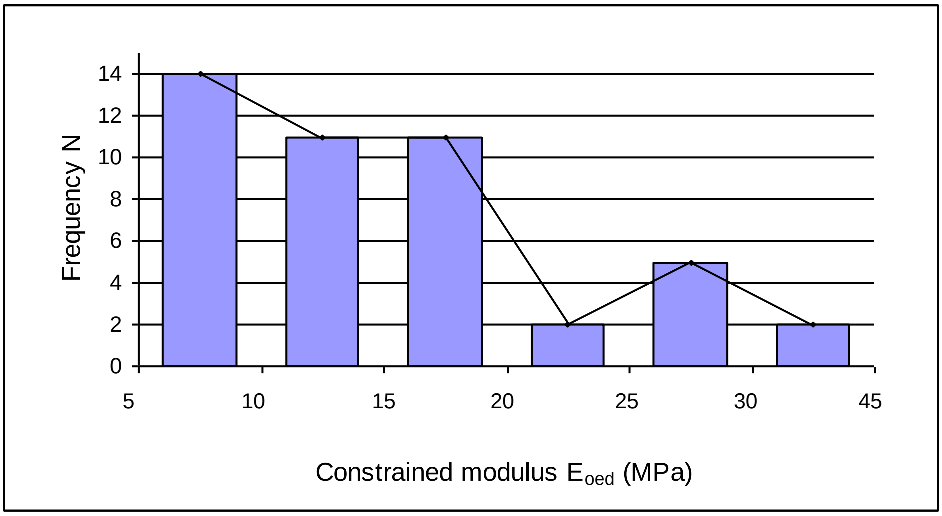


Fig.15 Dependence of constrained modulus on frequency

At the conclusion of this Chapter, the foundation soil typology of Neogene of Ostrava basin is presented. Local characterizations are marked beside them the Standard characterization is noted. Local characterizations are significant for foundation soil geotechnical assessment. Tab.2 shows the research results are more favourable then Standard characterization.

Tab.2 Comparison of local characterization with Standard characterization

	characterization	local characterization	Standard characterization
F8 (CH, CV, CE) *solid consistency* Sr>0,8	E_{oed} (MPa) E_{def} (MPa)	10,46 – 25,28 3,87 – 9,35	 4 – 6
	c_{ef} (MPa)	0,01 - 0,08	0,006 – 0,014
	φ_{ef} (°)	15 – 27	13 - 17
	c_u (MPa)	0,06 - 0,28	0,08
	φ_u (°)	1 – 8	0
	characterization	local characterization	Standard characterization
F8 (CH, CV, CE) *stiff consistency*	E_{oed} (MPa) E_{def} (MPa)	6,26 – 17,83 2,32 – 6,6	 2 – 4
	c_{ef} (MPa)	0,008 – 0,055	0,002 – 0,008
	φ_{ef} (°)	14 – 28	13 – 17
	c_u (MPa)	0,03 – 0,19	0,04
	φ_u (°)	3,3 - 12	0
	characterization	local characterization	Standard characterization
F7 (MH, MV, ME) *solid consistency* Sr>0,8	E_{oed} (MPa) E_{def} (MPa)	not available	 5 – 7
	c_{ef} (MPa)	0,01 – 0,08	0,008 – 0,016
	φ_{ef} (°)	17 – 27,92	15 - 19
	c_u (MPa)	0,119 – 0,135	0,08
	φ_u (°)	1,7 – 2,2	0
	characterization	local characterization	Standard characterization
F6 (CL, CI) *stiff consistency*	E_{oed} (MPa) E_{def} (MPa)	7,39 – 27,45 3,47 – 12,9	 3 – 6
	c_{ef} (MPa)	0,007 – 0,01	0,008 – 0,016
	φ_{ef} (°)	19 - 28	17 – 21
	c_u (MPa)	not available	0,05
	φ_u (°)	not available	0

Linear dependence of consistency degree, porosity and moisture on the *depth* under surface of Neogene were not approved (Fig. 16, 17, 18).

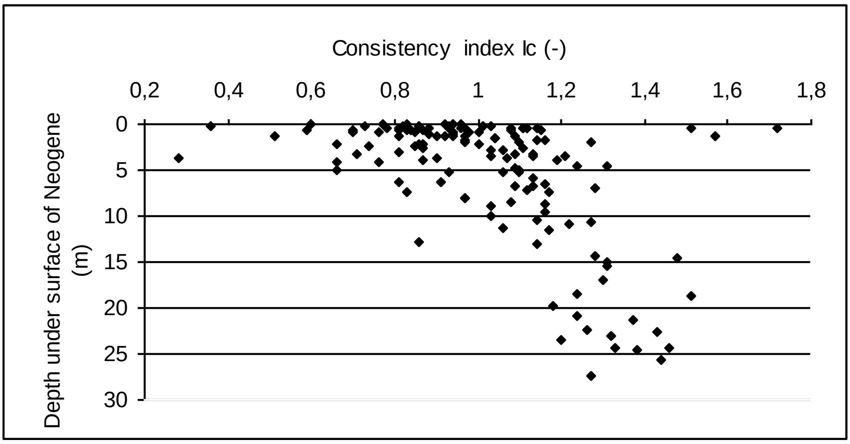


Fig.16 Dependence of consistency index on the depth below Neogene top

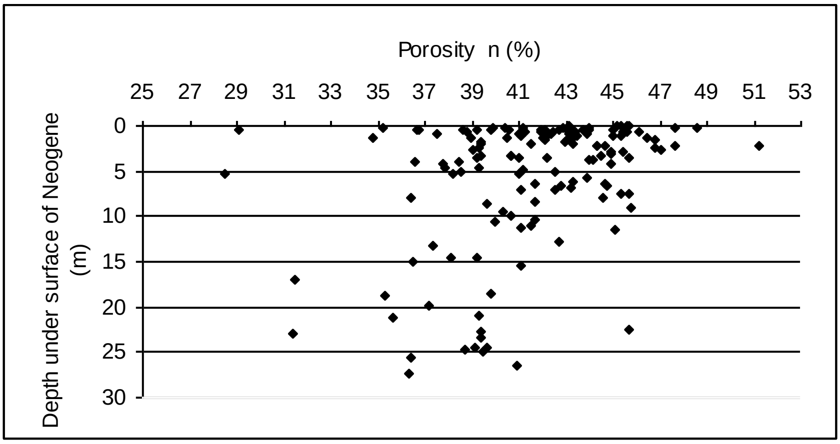


Fig.17 Dependence of porosity on the depth below Neogene top

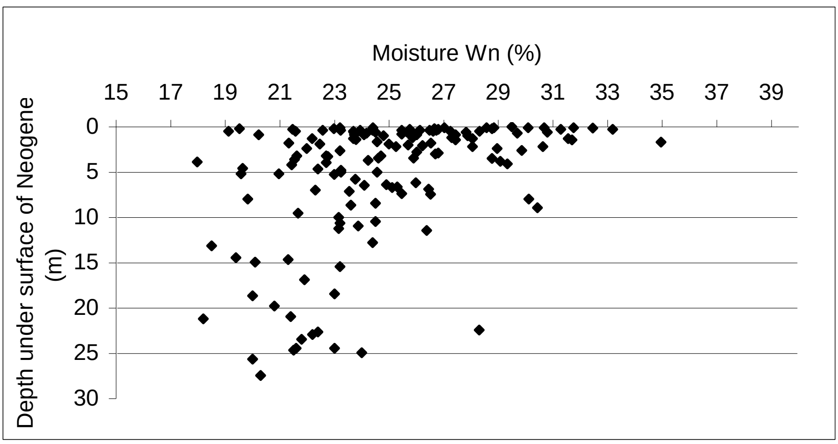


Fig.18 Dependence of moisture on the depth below Neogene top

Figure 19 and 20 show dependent bulk density and dry bulk density of soil on the porosity.

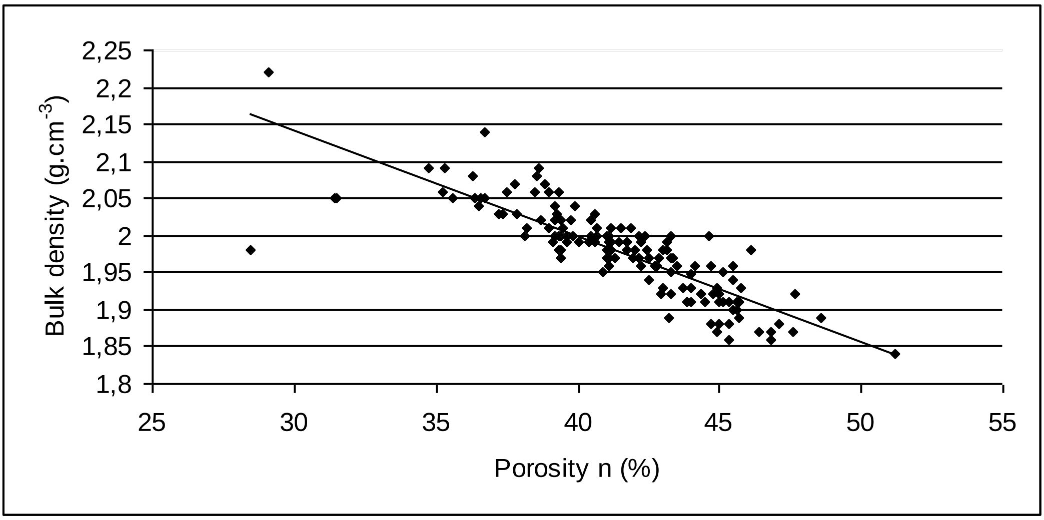


Fig.19 Dependence of bulk density on porosity

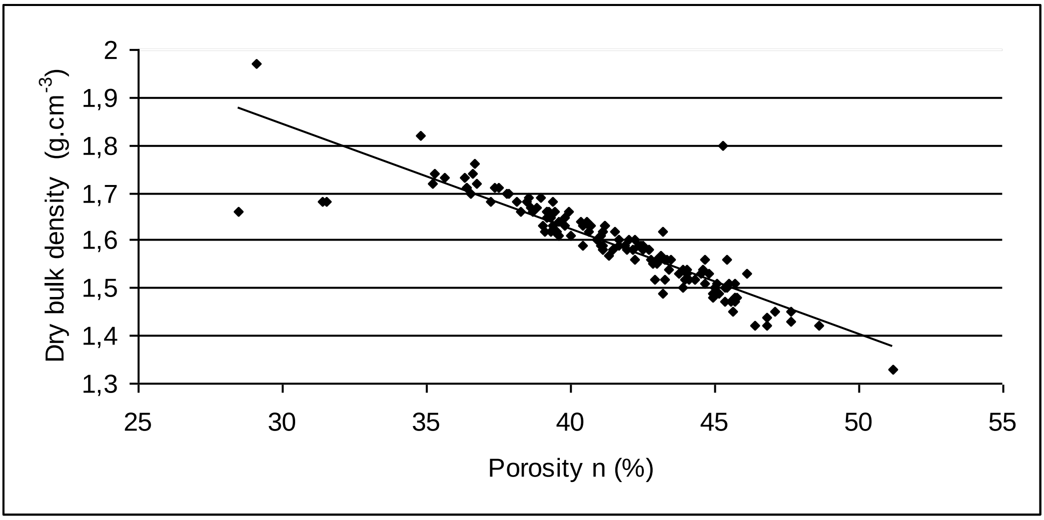


Fig.20 Dependence of dry bulk density on porosity

CONCLUSION

This engineering geological research assessed the physical and mechanical properties. On the base of this research, the typology of foundation soil local characterization of Neogene was created. The typology is suitable for the foundation engineering at the area of Ostrava Basin.

Neogene occurs in the depth of 1.8 to 19 meters below the earth surface at the area of Ostrava City. It has form of lower baden lutaceous deposits – grey-bluish, grey-greenish or grey limy clay. This soil is well sorted, prevailing stiff or solid (0.5 – 1.5 of consistency). The most frequently there occurs fine grained soil of F8, less F6 and F7.

Porosity varies from 28 to 51%, moisture from 12 to 35%. Bulk density varies from 1.8 to 2.2 g.cm-3, dry bulk density from 1.3 to 2 g.cm-3. Both depend on porosity. Dependence of physical properties (porosity, consistency index, moisture, saturation) on depth beneath the top of the Neogene was not approved.

Established mechanical properties – effective and total parameters of shear strength, constrained modulus and deformation modulus agree with the values of similar structures mentioned in technical literature.

Typology of foundation soil was created on the basis of soil type, consistency degree. These parameters are determining for fine grained soil (F6, F7, F8). Local characterization presented in Tab. 2 show more favourable geotechnical parameters relevant for foundation engineering.

The group of very unfavourable foundation soil was not unambiguously defined in given geological unit. Regarding to a file extent and imperceptible occurrence of loamy sand and sandy soil, continuation of this research is recommended. Continuation could lead to an extension of the database; influence of soil properties on the depth could be approved; occurrence of sandy soil could be discovered.

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ČSN EN ISO 14688-2 (721003) - Geotechnický průzkum a zkoušení - Pojmenování a zatřiďování zemin - Část 2: Zásady pro zatřiďování, Validity: 1.4.2005

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Since 1.6.2006 replace:

ČSN CEN ISO/TS 17892-3 (721007) - Geotechnický průzkum a zkoušení - Laboratorní zkoušky zemin - Část 3: Stanovení zdánlivé hustoty pevných částic zemin pomocí pyknometru, Validity: 1.5.2005

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Reviewer: Doc. Ing. Jarmila Müllerová, CSc.